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Aggregate Resources Inventory of West Nissouri Township Middlesex County Southern Ontario

By Staff of the Engineering and Terrain Geology Section
Ontario Geological Survey

1984

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Minister
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Deputy Minister

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Project Supervisor: Dale W. Scott and I. Szoke
Text Prepared by: J. Lynn Watson
Compilation and Drafting by: Staff of the Aggregate Assessment Office

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Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

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ABSTRACT

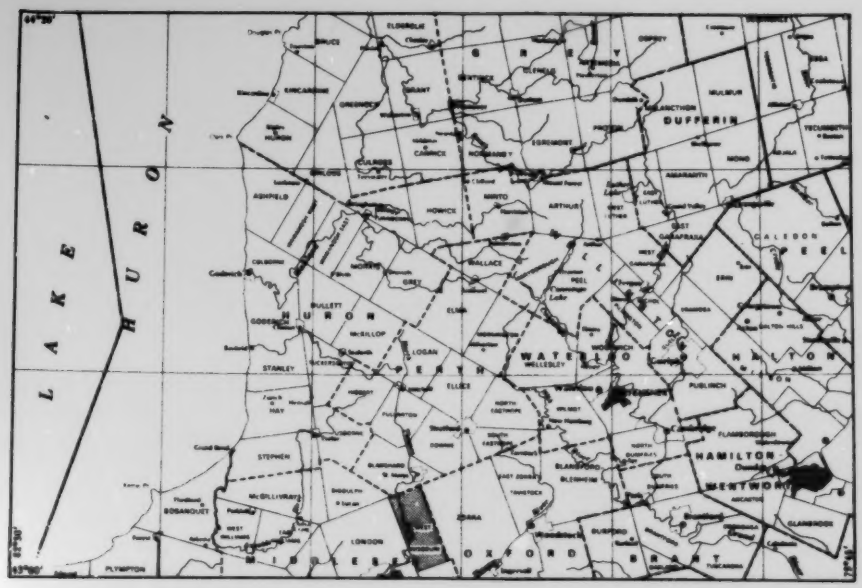

Figure 1 - Key Map Showing the Location of West Nissouri Township, Scale 1:1 800 000.

This report includes both an inventory and analysis of sand and gravel as well as bedrock resources in West Nissouri Township. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971.

In West Nissouri Township, four areas of glaciofluvial outwash containing significant amounts of sand and gravel have been selected for possible resource protection and/or development at the primary level. The Selected Sand and Gravel Resource Areas occupy 1090 acres (440 ha), exclusive of the licenced properties. An estimated 740 acres (300 ha) are currently available for extraction, containing possible resources of 38 million tons (34 million tonnes). The material is acceptable for a wide range of granular base course and hot-laid asphaltic products.

In addition, several outwash and ice-contact deposits have been selected as Sand and Gravel Resource Areas of Secondary Significance. Although these deposits are not the best resources, they should be considered as part of the township's aggregate supply. The remaining deposits are relatively less important and have been classified at the tertiary level.

The surficial deposits of West Nissouri are underlain by limestone of the Dundee Formation and limestone and dolostone of the Lucas Formation of the Detroit River Group. Although both units have economic value, the thickness of the drift cover may prohibit extraction, except for a small area along the North Thames River valley.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF WEST NISSOURI TOWNSHIP[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief, Engineering and Terrain Geology Section, May 19, 1984.
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PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Airphotos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

Deposits with potential for further extractive development or those where existing data are scarce, were studied in greater detail. Representative layers in these deposits were sampled in 25- to 100-pound (11 to 45 kg) units either from existing pit faces or from test pits dug by backhoe. The samples were analysed for grain size distribution and in some cases for petrographic assemblage. Analyses were performed by the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications. In areas of limited subsurface exposure, drilling using a powered hollow stem auger was undertaken. The stratigraphic sections in these test holes are described in drill logs included in the report as Table 7. In some cases samples taken during the course of the drilling were analysed to determine grain size distribution. The symbols for and locations of test hole sites are noted on Map 1.

In the office, the pit and field sample data were supplemented by information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Soil reports published by the Ontario Ministry of Agriculture and Food were also consulted in order to supply additional information in areas with limited data. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data

such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2). Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas lying outside of licenced properties that have previously been extracted (e.g. wayside pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favorable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot (0.3 m) thick section of dolostone, one acre (0.4 ha) in extent, assuming a bulk density of 165 pounds per cubic foot (2649 kg per cubic metre)).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) or approximately 3200 tons per acre (7173 tonnes per hectare). Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p. 7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

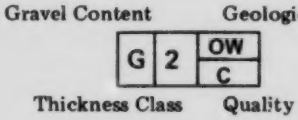
Map 1 is derived directly from the existing surficial geology maps of the area or from airphoto and field interpretation where surficial mapping is incomplete. It shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

The present level of extractive activity in the study area is indicated as follows. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit, as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The data from which these symbols are derived has been plotted on grain size distribution graphs. The relative amounts of gravel, sand, silt, and clay in the sampled material are shown graphically by the sub-

division of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. These areas are identified on Map 2 by different shading patterns. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a dark shading on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no shading. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indi-

cates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (or high silt and clay content) may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphaltic aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses such as concrete or structures. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

Analyses of unprocessed samples obtained from test holes and pits have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products — Granular Base Course A,B, and C; and Hot-Laid Asphaltic Sand Nos. 1, 2, 3, 4, 5, 6 and 8. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, power lines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but

readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three shades. The darkest shade indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and

Communications. The main characteristics and uses of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN WEST NISSOURI TOWNSHIP

LOCATION AND POPULATION

West Nissouri Township occupies an area of 59,274 acres (23 988 ha) in eastern Middlesex County. The township is bounded on the north, south, east and west by Blanshard Township, North Dorchester Township, the Township of Zorra and London Township, respectively. West Nissouri is shown on the Lucan (40 P/3) map sheet of the National Topographic System at a scale of 1:50 000.

The total population of West Nissouri Township has grown from 3158 in 1972 to 3300 in 1982 (Ontario Ministry of Municipal Affairs and Housing 1983; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). The dominant land use is agriculture with residential development concentrated mainly in small hamlets such as Crumlin, Thorndale, Plover Mills and Wellburn. There are also a large number of rural-nonfarm dwellings scattered across the township.

Road access is provided by county and township roads as well as by King's Highways 2 and 7 which form the southern and northern boundaries of the township, respectively. The township is also served by lines of the Canadian National and Canadian Pacific Railways which cross the township from the northeast to southwest corners and along the southern boundary, respectively.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

West Nissouri Township has a flat to gently undulating surface which slopes to the southwest at about 2 to 6 metres per kilometre. The surface is broken by several positive landform features, such as hummocky end moraines and ice-contact/kame hills which may have relief ranging from 15 to 100 feet (5 to 30 m). Depressions include the deeply incised meltwater channel now occupied by the North Thames River. The physiography of the area and land use activities are further discussed by Chapman and Putnam (1966). The reader is specifically referred to descriptions of three physiographic regions: the Stratford Till Plain (pp. 210-214); the Oxford Till Plain (pp. 231-233); and the Caradoc Sand Plains and the London Annex (pp. 236-238).

The physiography and distribution of surficial materials are the result of the repeated advance and melting back of massive, continental ice sheets. The most significant glacial events in West Nissouri Township occurred during the Late Wisconsinan Substage of the Pleistocene Epoch (informally known as the 'Great Ice Age'). The Late Wisconsinan lasted from approximately 23 000 to 10 000 years ago. Sado (1980 a,b) has described in detail the geological history of the West Nissouri map area. The following discussion draws primarily upon Sado's work.

About 23 000 years ago, glacial ice advanced across this region from the north and completely covered West Nissouri Township. This glacier deposited a consolidated, very stony, sandy silt till known as Catfish Creek Till (Sado 1980a). This coarse-textured, stony till is the source of much of the sand and gravel deposits in the region. The till's stony nature made it favourable for reworking into gravels of suitable size. Consequently, the Catfish Creek Till is often found in association with glaciofluvial sand and gravel of economic value. This is particularly true of the gravelly outwash in the southern part of West Nissouri Township which has been selected at both the primary and secondary levels of significance.

After a period of retreat of the glacial front during which mantles of sand, silt and clay were deposited in large proglacial lakes, the ice once again readvanced from the Lake Huron basin and deposited the Tavistock Till which now covers much of the township. This till is a gritty, clayey to sandy silt till occurring largely as ground moraine. Older, subdued features, such as the Arva and Dorchester Moraines, were overridden by the Tavistock ice and are covered by Tavistock Till, which in these areas is interbedded with layers of sand and gravel. However, the till, itself, is not a suitable source of aggregate because of its high fines content.

The gradual melting back of the Lake Huron glacier resulted in vast amounts of meltwater flowing southwestwards in a deeply incised channel now occupied by the North Thames River. The gravelly outwash flanking Fanshawe Park was originally deposited as a delta into glacial Lake London. As water levels retreated westward, the early river cut down through the

delta forming a succession of terraces and covering them with gravelly alluvium. Field investigation revealed a considerable depth of good quality coarse aggregate in these terraces and already there has been considerable extractive activity. Most of this outwash has been selected at the primary level of significance.

The margin of the Lake Huron ice was in confluence with ice from the Lake Erie basin along the Ingersoll Interlobate Moraine to the south of the township. The combined runoff from the two melting ice lobes deposited outwash sand and gravel which may cover a larger area than is indicated by present Quaternary mapping. A recent study by Sado (1980b) in neighbouring North Dorchester Township suggests that granular deposits from 50 to 75 feet (15 to 23 m) thick underlie much of the surface. The quality of the aggregate is undetermined, although Sado (1980b, p. 8) believes a figure of 10 to 25 percent fine gravel would be reasonable. A potential for buried material may exist in West Nissouri Township in the vicinity of the Dorchester Moraine (E.V. Sado, Quaternary Subsection Supervisor, Ontario Geological Survey, Toronto, personal communication, 1981). However, this possibility has not yet been confirmed.

As the Lake Huron ice continued to melt, glacial lakes developed against the ice margins, depositing glaciofluvial and glaciolacustrine material. During the formation of these lakes, Sado (1980a, p. 94) states that the ice appears to have been partially afloat, forming an ice shelf. Large quantities of ice-contact stratified drift were deposited subaqueously beneath these ice shelves. The ice-contact zones near Cobble Hill and Cherry Grove can be attributed to this process. These areas consist of sandy kame hills, in the Cobble Hill area rising to 100 feet (30 m) above the surrounding till plain. Although the material is predominantly sandy and interspersed with Tavistock Till, the kame knolls may contain gravel pockets suitable for aggregate extraction.

The eventual draining of the glacial lakes marked the end of glacial activity in the area. Geological processes of recent times have been of minor importance in modifying the landscape of the township.

EXTRACTIVE ACTIVITY

At least twenty-seven sand and gravel pits have been opened in West Nissouri Township in the past. The pits are concentrated in the Fanshawe Delta outwash deposit and in the northern limits of the Dorchester Moraine. However, many pits became inactive in 1971 when the township was designated under The Pits and Quarries Control Act, 1971. At the time of writing, twenty-one pits were licenced for extraction with a total area of 1302.9 acres (527.3 ha). Production figures for the licenced properties have been maintained by the Aylmer District Office of the Ontario Ministry of Natural Resources since designation of the township. The average annual production between 1976 and 1980 was approximately 733,155 tons (665 118 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular materials. The total extent of these deposits is approximately 12,300 acres (5000 ha), representing an original tonnage of 530 million tons (480 million tonnes). Many of these deposits have limited value for reasons of size, thickness or quality of the material. Consequently, only the most significant sources are selected at the primary level.

The four sources of primary significance are shown on Map 2; three are glaciofluvial outwash belonging to the North Thames River meltwater channel and the Fanshawe Delta and one is outwash associated with the Dorchester Moraine. These deposits contain good quality sand and gravel with average depths ranging up to 25 feet (8 m). The primary areas total 1090 acres (440 ha), exclusive of the licenced properties. Cultural constraints and previous extraction reduce the area presently available to 740 acres (300 ha). Using an average deposit thickness for each resource area, the total available sand and gravel resources selected at the primary level are estimated to be 38 million tons (34 million tonnes) or 7 percent of the original tonnage.

Sandy outwash associated with the Dorchester Moraine, small areas of gravelly outwash belonging to the Fanshawe Delta and North Thames meltwater channel and several deposits of ice-contact stratified drift have been

selected at the secondary level of significance. Although these are not the 'best' resources, they should be considered as part of the township's aggregate supply. Other deposits are less important and have been classified at the tertiary level.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is an outwash deposit which forms part of the Fanshawe Delta. In general, the material consists of horizontally bedded, moderately sorted sand and gravel with depths of up to 50 feet (15 m). The beds vary in composition and thickness throughout the area, reflecting their deltaic mode of origin.

A large portion of Area 1 is currently licenced for extraction. At the time of field investigation, there were thirteen licenced pits, including active pits, properties that had not yet been developed, and several in varying stages of rehabilitation (pit nos. 4-11, 16-19, 21). The active pits had faces ranging from 5 to 30 feet (1.5 to 9 m) high and exposed moderately sorted, coarse gravel layers mixed with coarse sand. The beds were often quite distinct and contained rounded to subangular particles ranging from pebbles to oversize. Sandy faces exhibited crossbedding structures. Examination of these pits indicated that the material coarsens towards Fanshawe Lake. Pits in the northern portion of the area had an overall gravel content of 60 to 70 percent, while those nearest the lake averaged 80 to 90 percent. The latter pits also contained sections of calcium carbonate cementation which was not observed further to the north.

The aggregate quality is generally good. However, oversized material is present in objectionable quantities and must be removed or crushed. The aggregate also has a high chert content which makes the product undesirable for surface paving and structural concrete uses. The chert content may be reduced by selective screening and the removal of the particle sizes in which chert is most often found. A high silt content in some areas necessitates washing to remove the excess fines. Despite these limitations, data obtained from the Ontario Ministry of Transportation and Communications (M.T.C.) showed that the aggregate is acceptable for a range of granular base course and hot-laid asphalt products.

Resource Area 1 occupies 410 acres (165 ha), exclusive of the licenced properties. Deletions for cultural setbacks reduce the area presently available to 260 acres (105 ha). Assuming an average deposit thickness of 25 feet (8 m), sand and gravel resources are estimated to be 16 million tons (14 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is a gravel outwash deposit which is also part of the Fanshawe Delta and has many characteristics in common with Resource Area 1. Golder Associates (1979) noted extensive strata of sand and gravel in this area. A bore hole in West Nissouri Township was terminated after penetrating 30 feet (9 m) of granular material (Golder Associates 1979, p. 9).

There is one licenced pit (pit no. 20) in this Resource Area, and there are two licenced properties located in the same deposit in neighbouring London Township. Face heights range from 10 to 20 feet (3 to 6 m) and gravel contents are 60 to 85 percent. One of the pits exposed horizontal layers of moderately sorted, fine to medium-coarse gravel, interbedded with medium to coarse sand. Quality limitations include excess fines, sections of calcium carbonate cementation and oversize material in quantities up to 15 percent. Data obtained from M.T.C. indicated the material is acceptable for granular base course products and hot-laid stone.

Resource Area 2 contains approximately 165 acres (67 ha) which are currently available for resource conservation. Assuming an average deposit thickness of 22 feet (7 m), estimated sand and gravel resources are 9 million tons (8 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 is a gravel outwash deposit associated with the Huron-Erie interlobate zone. The Dorchester Moraine makes up part of this area and the terrain has a typically rolling to hummocky relief with some swampy depressions. The moraine is a complex feature composed of up to 12 feet (4 m) of sandy Tavistock Till resting upon older sand and gravel interlain with layers of till. These layers of till within the sand and gravel were presumably deposited by blocks of

ice in a stagnant environment (Sado 1980a, p. 71).

Three licenced properties (pit nos. 1, 2 and 3) and one unlicenced property (pit no. 26) are located in the Area. Face heights range from 10 to 20 feet (3 to 6 m) and expose poorly sorted and bedded, medium to coarse, rounded to subangular gravel mixed with coarse sand and clay particles. A large proportion of the pebbles were 2 to 4 inches (5 to 10 cm) in size and some oversized material was observed, although in acceptable quantities. The overall gravel content was 70 to 80 percent. All of these pits have been partially excavated to below the water table.

Field investigation of pits in both West Nissouri and North Dorchester indicates that the deposit tends to be variable, with gravel often occurring in pockets. The pits do, however, contain sufficient cobbles and boulders to permit economic crushing. Granular Base Course (G.B.C.) A, B and Hot-Laid No. 4 surface paving aggregate can, therefore, be produced by selective screening and sand control. Selective screening also minimizes the undesirable chert and shale content. The sand fraction grades coarse and dirty and blending is necessary for hot-laid asphalt products (M.T.C.). Minor cementation may also be a problem where the aggregate is overlain by till.

Resource Area 3 occupies 240 acres (97 ha), exclusive of the licenced properties. Deletions for cultural setbacks and previous extraction leave 155 acres (63 ha) currently available. Assuming an average deposit thickness of 22 feet (7 m), resources of sand and gravel are approximately 8 million tons (7 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Sand and Gravel Resource Area 4 is a gravel outwash deposit which is part of the Fanshawe Delta. Accordingly, the material has many characteristics in common with Resource Areas 1 and 2. The most important similarities are the variability in composition and thickness of the beds, as well as the coarseness of the material.

There were four licenced properties (pit nos. 12 to 15) and one unlicenced property (pit no. 25) in the deposit. The pits had faces ranging in height from 5 to 10 feet (1.5 to 3 m). An 8-foot (2 m) face in pit 13, for example, contained 4 feet (1.2 m) of well bedded, poorly sorted, rounded to subangular, fine to coarse gravel mixed with coarse sand. The pebbles were up to 2 inches (5 cm) in size. A distinct break separated this material from the underlying beds of wet fine sand. At the time of observation, aggregate was being dredged from below the water table. The overall gravel content was 60 to 70 percent, but with objectionable quantities of chert and oversize. The remaining pits contained similar material. The aggregate is acceptable for a range of products.

Resource Area 4 occupies 200 acres (81 ha), exclusive of the licenced properties. Deletions for cultural setbacks and previous extraction reduce the area to 155 acres (63 ha). Assuming an average deposit thickness of 12 feet (4 m), sand and gravel resources are approximately 5 million tons (4 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

A gravel outwash deposit located in close proximity to the Fanshawe Delta is approximately 12 feet (4 m) thick and occupies a former small meltwater channel. A shallow face in licenced pit no. 15 contained moderately bedded, poorly sorted, fine to coarse gravel mixed with dirty, coarse sand. The pebbles were up to 3 inches (8 cm) in size and the overall gravel content was 70 to 80 percent. Material was being dredged from below the water table at the time of observation. Data obtained from M.T.C. indicated the material is acceptable for G.B.C. B, 16 mm crushed and possibly hot-laid asphaltic sand.

A smaller gravel outwash deposit is located along the North Thames River on the Blanshard-West Nissouri boundary. The outwash occurs as an elevated terrace in the former meltwater channel and has a maximum thickness of 25 feet (8 m). An overgrown pit was observed in the deposit. A licenced property in neighbouring Blanshard Township showed a gravel content of approximately 30 percent.

A sandy kame deposit is located on the eastern boundary of the township near Cobble Hill. One unlicenced property (pit no. 24) had a face of 10 to 15 feet (3 to 5 m) which contained fine sand interrupted by pockets of poorly sorted, subangular coarse gravel mixed with medium sand. The gravel content ranged from

30 to 50 percent.

Further to the south are two gravel ice-contact deposits which are situated on either side of Waubuno Creek and fall within the northern region of the Dorchester Moraine. Although no pits have been opened, water well records show a thickness of 12 to 17 feet (4 to 5 m) of highly variable sand and gravel interbedded with till.

Finally, two areas of sandy outwash have been selected at the secondary level. These deposits are also part of the Dorchester Moraine and consequently, are variable in composition. A licenced pit in North Dorchester Township exposed 5 to 15 feet (1.5 to 5 m) of silty fine sand with some clay and traces of coarse sand and fine gravel. The sand has been used for blending and is acceptable for select subgrade aggregate.

BEDROCK GEOLOGY

The bedrock surface of West Nissouri is relatively subdued with a gentle slope to the southwest of approximately 3 metres per kilometre. The drift thickness averages 100 to 150 feet (30 to 46 m) except along part of the North Thames River valley where the thickness is less than 50 feet (15 m).

The Lucas Formation of the Detroit River Group is the oldest bedrock unit and underlies a small area in the northeast corner of the township. The formation is approximately 190 feet (58 m) thick in this area and is predominantly dolostone with interfingers of high-calcium limestone. The dolostone is largely soft, evenly bedded, uniform, light to medium brown, fine grained and often contains bituminous laminae (Hewitt and Vos 1972, p. 63). Massive, fossiliferous, high-purity calcium limestone reefs also occur. The formation has been extensively quarried near Beachville in the Township of Zorra where the limestone facies predominates. The limestone is used for flux stone, and in the production of lime and portland cement. Although the rock of the dolostone facies has a potential for economic value, the excessive drift thickness in West Nissouri prevents economic extraction.

The Dundee Formation overlies the Lucas Formation in the remainder of the township. The Dundee Formation ranges in thickness from 60 to 160 feet (18 to 49 m) and consists of light brown, medium-grained limestone with some chert present (Hewitt 1972, p. 12). The limestone is quarried to the north at St. Marys (Blanshard Township) for the manufacture of portland cement and elsewhere in southwestern Ontario for crushed stone. Quarrying may be possible in a thinly drift-covered area along the North Thames River valley. However, in the rest of West Nissouri Township drift cover ranges from 50 to over 150 feet (15 to 46 m).

SUMMARY

The sand and gravel deposits of West Nissouri Township are mainly the product of glacial activity which occurred during the 'Great Ice Age'. Good quality coarse aggregate is available in the outwash deposits of the Fanshawe Delta and Dorchester Moraine areas. Additional outwash resources are located in areas of secondary value adjacent to the delta and moraine and also in the northwest corner of the township. Ice-contact deposits of secondary value are located along Waubuno Creek and near Cobble Hill. Field investigation revealed several quality limitations which are common to many of the pits in West Nissouri. These include a high chert and fines content, objectionable quantities of oversized material and a generally high water table. The aggregate is, nevertheless, acceptable for a range of products.

Two bedrock units underlie the surficial material. Limestone of the Lucas Formation (Detroit River Group) has been quarried in neighbouring townships for the production of flux stone, lime and portland cement. The limestone of the overlying Dundee Formation has also been quarried for crushed stone and the manufacture of portland cement. With the exception of a small, narrow area along the North Thames River valley, drift cover is generally too great to permit economic extraction in West Nissouri.

Enquiries regarding the Aggregate Resources Inventory of West Nissouri Township should be directed to the Ontario Ministry of Natural Resources either at the Aylmer District Office, 353 Talbot Street West, Aylmer, Ontario, N5H 2S8 (Tel. (519) 773-9241) or at the Southwestern Region Geological Office, 458 Central Avenue, London, Ontario, N6B 2E5 (Tel. (519) 433-8431).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, WEST NISSOURI TOWNSHIP

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	G-OW	2030 (820)	122 (111)
2	G-AL	20 (8)	1 (1)
	G-OW	405 (164)	10 (9)
	G-IC	1520 (620)	63 (57)
	S-OW	1390 (560)	50 (45)
	S-IC	2440 (990)	106 (96)
3	G-OW	740 (300)	19 (17)
	G-IC	32 (13)	1 (1)
	S-OW	520 (210)	18 (16)
	S-IC	970 (395)	29 (26)
	S-AL	1340 (540)	80 (73)
	S-LP	680 (275)	27 (24)
4	S-LP	260 (105)	3 (3)
		12,300 (5000)	530 (480)

N.B. Minor variations in the tables are caused by rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, WEST NISSOURI TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1	105	Murray Pucula	1	VI	18.7 (7.6)	sloped faces	partially rehabilitated
2	62	W.E. McLaughlin & Sons Ltd.	NE¼1	V	14.0 (5.7)	10-15 (3-5)	70-80 sloughed & partially over-grown, excavated below water table
3	158	Towland-Hewitson Const. Ltd.	2	V	11.3 (4.6)	10-15 (3-5)	70-80 sloughed & partially over-grown, excavated below water table
4	147	Township of West Nissouri (# 1)	10	I	20.0 (8.1)	20-25 (6.8)	80-90 sloughed & partially overgrown
5	–	T.C.G. Materials Ltd.	W½10	I	70.0 (28.3)	5-8 (1.5-2)	80-90 partially over-grown, water in pit
6	11	South Winds Sand & Gravel Ltd.	11, 12	I	52.0 (21.0)	15 (5)	70-80
7	53	Towland Hewitson Const. Ltd.	11, 12 & 13	II	287.0 (116.2)	15-20 (5-6)	80-90 east pit – partially overgrown north pit – no excavation
8	–	Standard Aggregates – A division of Standard Industries Ltd.	12	II	93.2 (37.7)	8-10 (2-3)	70-80 sloughed & partially overgrown
9	160	T.C.G. Materials Ltd.	W½12	II	40.5 (16.4)	10-15 (3-5)	50-60 sloughed & partially overgrown water in pit
10	99	South Winds Sand & Gravel Ltd. (# 1)	E½13	II	10.2 (4.1)	15 (5)	70-80

TABLE 2 | SAND AND GRAVEL PITS, WEST NISSOURI TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
11	99	South Winds Sand & Gravel Ltd. (# 2)	E½13	II	25.0 (10.1)	–	no excavation
12	17	F.B. Ware (409664 Ontario Ltd.)	12, 13	III	48.5 (19.6)	–	60-70 no excavation
13	–	Ware's Family Pit	12, 13	III	25.0 (10.1)	5-10 (1.5-3)	60-70 partially overgrown, excavated below water table
14	–	Township of West Nissouri	W½13	III	10.0 (4.0)	5-10 (1.5-3)	60-70 sloughed & partially overgrown, water near surface
15	69	Bre-ex Ltd.	NW¼13	III	53.0 (21.4)	5-8 (1.5-2)	70-80 water near surface
16	7	Canada Building Materials Co.	14, 15	II	135.0 (54.6)	25-30 (8-9)	60-70
17	163	Corp. of County of Middlesex	14, 15	II	74.0 (30.0)	25-30 (8-9)	60-70
18	168	Canada Building Materials Co.	15	II	67.0 (27.1)	25-30 (8-9)	60-70 partially rehabilitated
19	–	Towland (London) 1970 Ltd.	Pt. E½ & W½ 11	I	152.5 (61.7)	–	no excavation
20	–	Stebbins Paving & Const. Ltd.	13	I	62.2 (25.2)	10-20 (3-6)	60-85
21	–	South Winds Sand & Gravel Ltd.	16	II	33.8 (13.7)	–	no excavation
					1302.9 (527.3)		
UNLICENCED PITS*							
22	–	Poole	35	V	–	8-10 (2-3)	40-50 partially overgrown

TABLE 2 | SAND AND GRAVEL PITS, WEST NISSOURI TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
23	135	Leo Walsh	31	III	–	15-20 (5-6)	40-50 sloughed & partially overgrown
24	–	Peter Poel	13	VII	–	10-15 (3-5)	30-50 sloughed & partially overgrown
25	–	Lagrou	11	III	–	<10 (<3)	60-70 water in pit
26	157	Murray Pucula	2	VI	–	20 (6)	70-80 (irrigation pit)
27	85	Riddick	1	VII	–	15 (5)	35 sloughed & partially overgrown, water in pit

* Abandoned or wayside pits operating on demand under authority of a permit.

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, WEST NISSOURI TOWNSHIP

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1	410 (165)	150 (61)	0 (0)	260 (105)	25 (8)	16 (14)
2	240 (97)	75 (30)	0 (0)	165 (67)	22 (7)	9 (8)
3	240 (97)	75 (30)	10 (4)	155 (63)	22 (7)	8 (7)
4	200 (81)	40 (16)	5 (2)	155 (63)	12 (4)	5 (4)
	1090 (440)	340 (138)	15 (6)	740 (300)		38 (34)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, WEST NISSOURI TOWNSHIP

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
3-25 (1-8)	Dundee	60 (18)	210 (85)	45 (41)
25-50 (8-15)	Dundee	60 (18)	280 (113)	60 (54)
			490 (198)	105 (95)

TABLE 5 | QUARRIES, WEST NISSOURI TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

– NONE –

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, WEST NISSOURI TOWNSHIP

1 **DEPOSIT NO.**	2 **DEPTH OF OVERBURDEN** Feet (Metres)	3 **UNLICENCED AREA** Acres (Hectares)	4 **CULTURAL SETBACKS** Acres (Hectares)	5 **EXTRACTED AREA** Acres (Hectares)	6 **AVAILABLE AREA** Acres (Hectares)	7 **ESTIMATED WORKABLE THICKNESS** Feet (Metres)	8 **AVAILABLE RESOURCES** Millions of Tons (Tonnes)

– NONE –

TABLE 7 | SUMMARY OF TEST HOLE DATA, WEST NISSOURI TOWNSHIP

– NONE –

REFERENCES

Association of Professional Engineers of Ontario
1976: Performance Standards for Professional Engineers Advising on and Reporting on Oil, Gas and Mineral Properties; Association of Professional Engineers of Ontario, 11 p.

Chapman, L.J. and Putnam, D.F.
1966: The Physiography of Southern Ontario; Second Edition, University of Toronto Press, 386 p.

Golder Associates
1979: Subsurface Investigation, Preliminary Aggregate Evaluation, Fanshawe Park Resource Inventory; Report to Upper Thames River Conservation Authority, 20 p., 3 tables, 17 figures, unpublished report.

Hewitt, D.F.
1972: Paleozoic Geology of Southern Ontario; Ontario Division of Mines, Geological Report 105, 18 p. Accompanied by Map 2254, scale 1:1 013 760.

Hewitt, D.F. and Vos, M.A.
1972: The Limestone Industries of Ontario; Ontario Division of Mines, Industrial Mineral Report 39, 79 p. Accompanied by Map 2264, scale 1:1 013 760.

Ontario
1983: The Pits and Quarries Control Act, 1971; Revised Statutes of Ontario, 1980, Chapter 378, Queen's Printer for Ontario.

Ontario Interministerial Committee on National Standards and Specifications (Metric Committee)
1975: Metric Practice Guide; 67 p.

Ontario Ministry of Municipal Affairs and Housing
1983: Municipal Directory 1983; Queen's Printer for Ontario, 241 p.

Ontario Ministry of Natural Resources
1980: Statistics 1980; Ontario Ministry of Natural Resources, 122 p.

Ontario Ministry of Treasury, Economics and Intergovernmental Affairs
1974: 1974 Municipal Directory; Queen's Printer for Ontario, 128 p.

Robertson, J.A.
1975: Mineral Deposit Studies, Mineral Potential Evaluation, and Regional Planning in Ontario; Ontario Division of Mines, Miscellaneous Paper 61, 42 p.

Sado, E.V.
1980a: The Quaternary Stratigraphy and History of the Lucan Map Area, Southwestern Ontario; Unpublished MSc. Thesis, University of Waterloo, 146 p.
1980b: Sand and Gravel in North Dorchester Township, Middlesex County, Ontario; Ontario Geological Survey, Open File Report 5312, 18 p.

Sado, E.V. and Jones, D.
1980: Drift Thickness of the Lucan Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P. 2359, Drift Thickness Series, scale 1:50 000.

Sado, E.V. and Vagners, U.J.
1975: Quaternary Geology of the Lucan Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P. 1048, Geological Series, scale 1:50 000.

Sanford, B.V.
1969: Geology of the Toronto-Windsor Area, Ontario; Geological Survey of Canada, Map 1263A, scale 1:250 000.

APPENDIX A - SUGGESTED ADDITIONAL READING

American Geological Institute
1972: Glossary of Geology; Washington, D.C., 858 p.

Bauer, A.M.
1970: A Guide to Site Development and Rehabilitation of Pits and Quarries; Ontario Department of Mines, Industrial Mineral Report 33, 62 p.

Cowan, W.R.
1977: Toward the Inventory of Ontario's Mineral Aggregates; Ontario Geological Survey, Miscellaneous Paper 73, 19 p.

Fairbridge, R.W. (ed.)
1968: The Encyclopedia of Geomorphology; Encyclopedia of Earth Sciences, Vol. III, Reinhold Book Corp., N.Y., 1295 p.

Flint, R.F.
1971: Glacial and Quaternary Geology, John Wiley and Sons Inc., 892 p.

Hewitt, D.F.
1960: The Limestone Industries of Ontario; Ontario Department of Mines, Industrial Mineral Circular 5, 177 p.
1964a: Building Stones of Ontario, Part I Introduction; Ontario Department of Mines, Industrial Mineral Report 14, 43 p.
1964b: Building Stones of Ontario, Part II Limestone; Ontario Department of Mines, Industrial Report 15, 43 p.
1964c: Building Stones of Ontario, Part III Marble; Ontario Department of Mines, Industrial Mineral Report 16, 89 p.
1964d: Building Stones of Ontario, Part IV Sandstone; Ontario Department of Mines, Industrial Mineral Report 17, 57 p.
1972: Paleozoic Geology of Southern Ontario; Ontario Division of Mines, Geological Report 105, 18 p.

Hewitt, D.F. and Karrow, P.F.
1963: Sand and Gravel in Southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151 p.

Hewitt, D.F. and Vos, M.A.
1970: Urbanization and Rehabilitation of Pits and Quarries; Ontario Department of Mines, Industrial Mineral Report 34, 21 p.

Lowe, S.B.
1980: Trees and Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario; Ontario Ministry of Natural Resources, 71 p.

McLellan, A.G.; Yundt, S.E. and Dorfman, M.L.
1979: Abandoned Pits and Quarries in Ontario; Ontario Geological Survey, Miscellaneous Paper 79, 36 p.

Ontario Mineral Aggregate Working Party
1977: A Policy for Mineral Aggregate Resource Management in Ontario; Ontario Ministry of Natural Resources, 232 p.

Ontario Ministry of Natural Resources
1975: Vegetation for the Rehabilitation of Pits and Quarries; Forest Management Branch, Division of Forests, 38 p.

Peat, Marwick & Partners and
M.M. Dillon Limited
1981: Mineral Aggregate Transportation Study; Industrial Minerals Background Paper 1, 133 p. Summary Report 26 p.

Proctor and Redfern Limited
1974: Mineral Aggregate Study, Central Ontario Planning Region; Prepared for the Ontario Ministry of Natural Resources, over 100 p.

Proctor and Redfern Limited and
Gartner Lee Associates Limited
1975: Mineral Aggregate Study of Part of The Eastern Ontario Region; Prepared for the Ontario Ministry of Natural Resources, about 200 p.
1977: Mineral Aggregate Study and Geological Inventory, Southwestern Region of Ontario; Prepared for the Ontario Ministry of Natural Resources, about 200 p.

APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

ALKALI-AGGREGATE REACTION

A chemical reaction between the alkalies of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

BLENDING

Required in cases of extreme coarseness, fineness or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

CAMBRIAN

The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

CRUSHABLE AGGREGATE

Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited

in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

HOT-LAID (OR ASPHALTIC) AGGREGATE

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2, 6 and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

PETROGRAPHIC EXAMINATION

An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

POSSIBLE RESOURCE

Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

SILURIAN

An early period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAINS (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN DEPOSITS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS

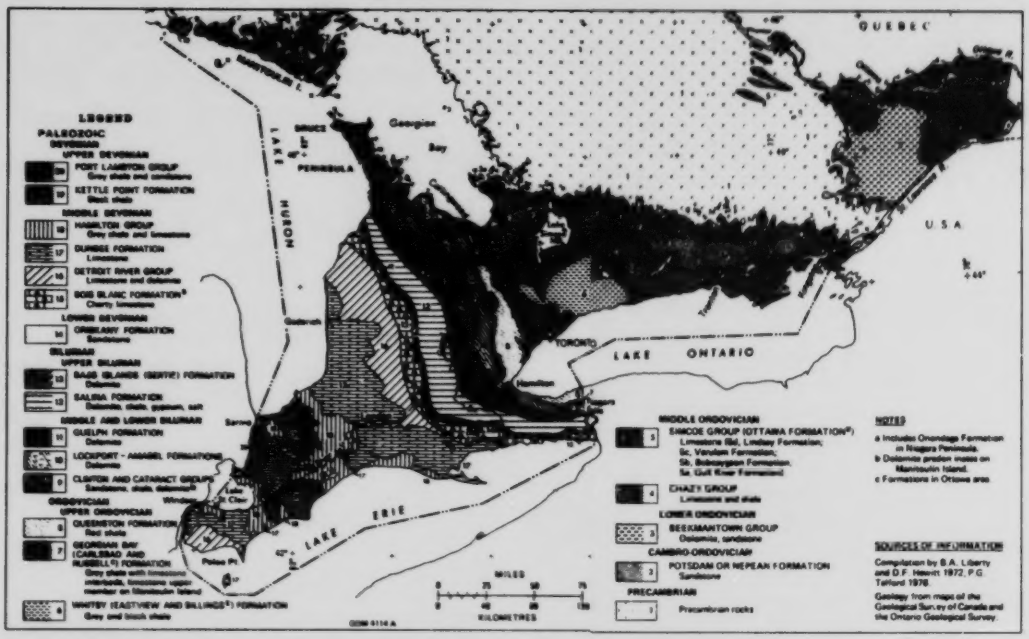


Figure 2 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone.

Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for

crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular-weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for cement. The formation is unsuitable for crushed stone due to clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in Metro Toronto and Cooksville produce brick and structural tile. Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum.

The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto) Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.

BLANSHARD TP
WEST NISSOURI TP
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CO OF MIDDLESEX
BIDDULPH TP
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Power Transmission Line
Auto Wreckers
Devizes
Kellys
Belton
Ditch
Oil Pipeline (underground)
St Ives
Poultry Farm
CANADIAN NATIONAL
Oliver
Pumping Sta
Plover Mills
BM 1048
Control Valve
Gas Pipeline (underground)
THAMES
Friendly Corners
Creek
Dugout
Dam
Orchard
Pump
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LONDON TP
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Ontario

Ministry of Natural Resources

Hon. Alan W. Pope
Minister

J. R. Sloan
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

WEST NISSOURI TOWNSHIP
COUNTY OF MIDDLESEX

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **40 P/3**

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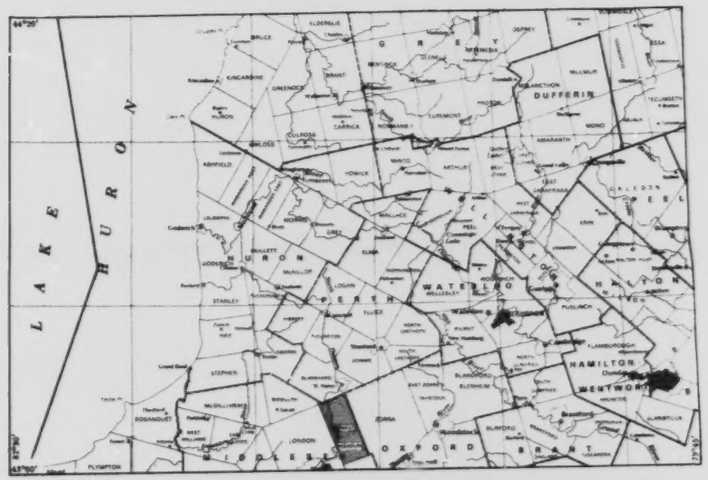


SYMBOLS

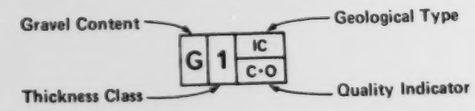
(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

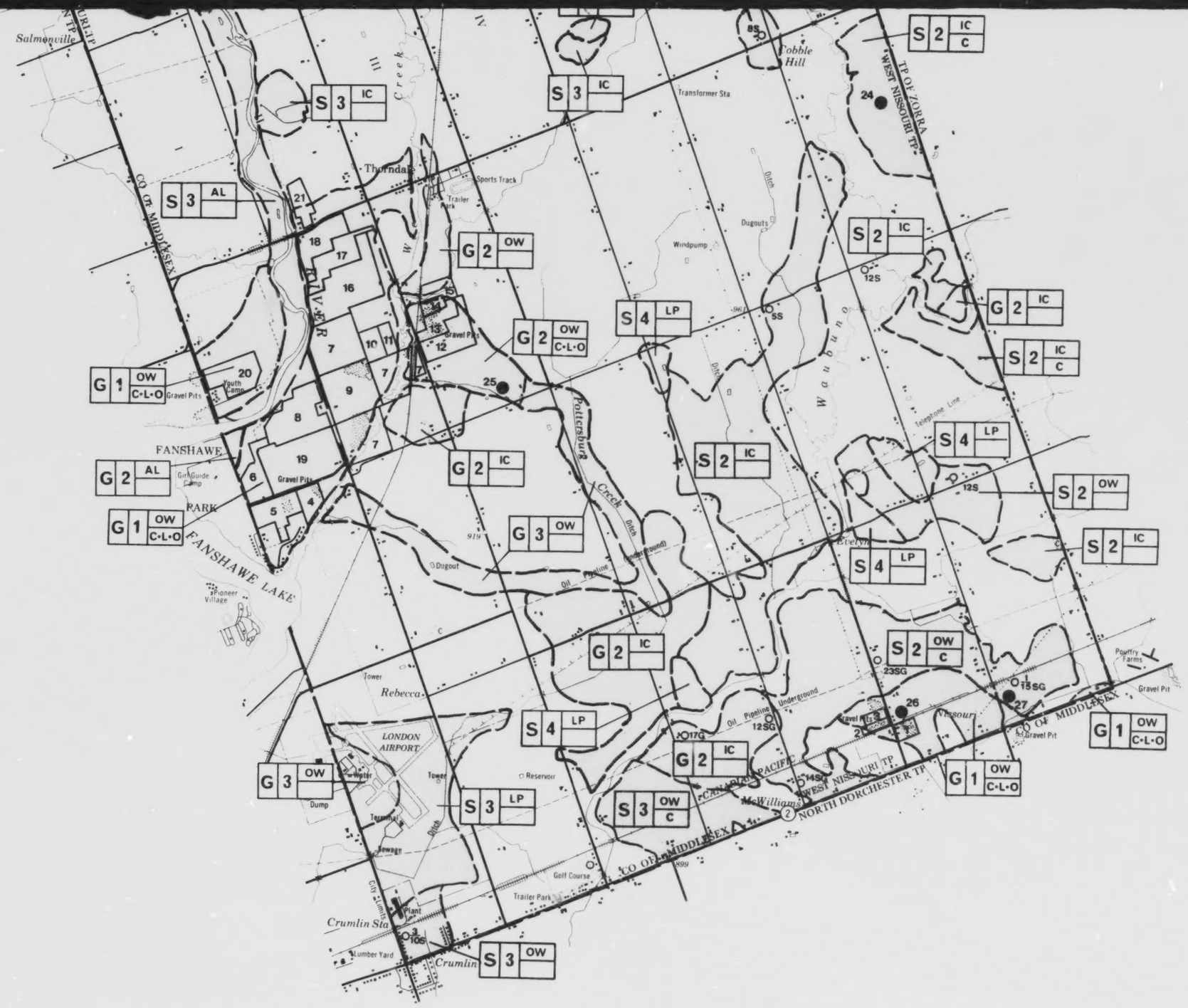
Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

DEPOSIT SYMBOL



Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and



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of a circle into proportional
thetical sample consisting of 4

Base map by Surveys and Map
sources.

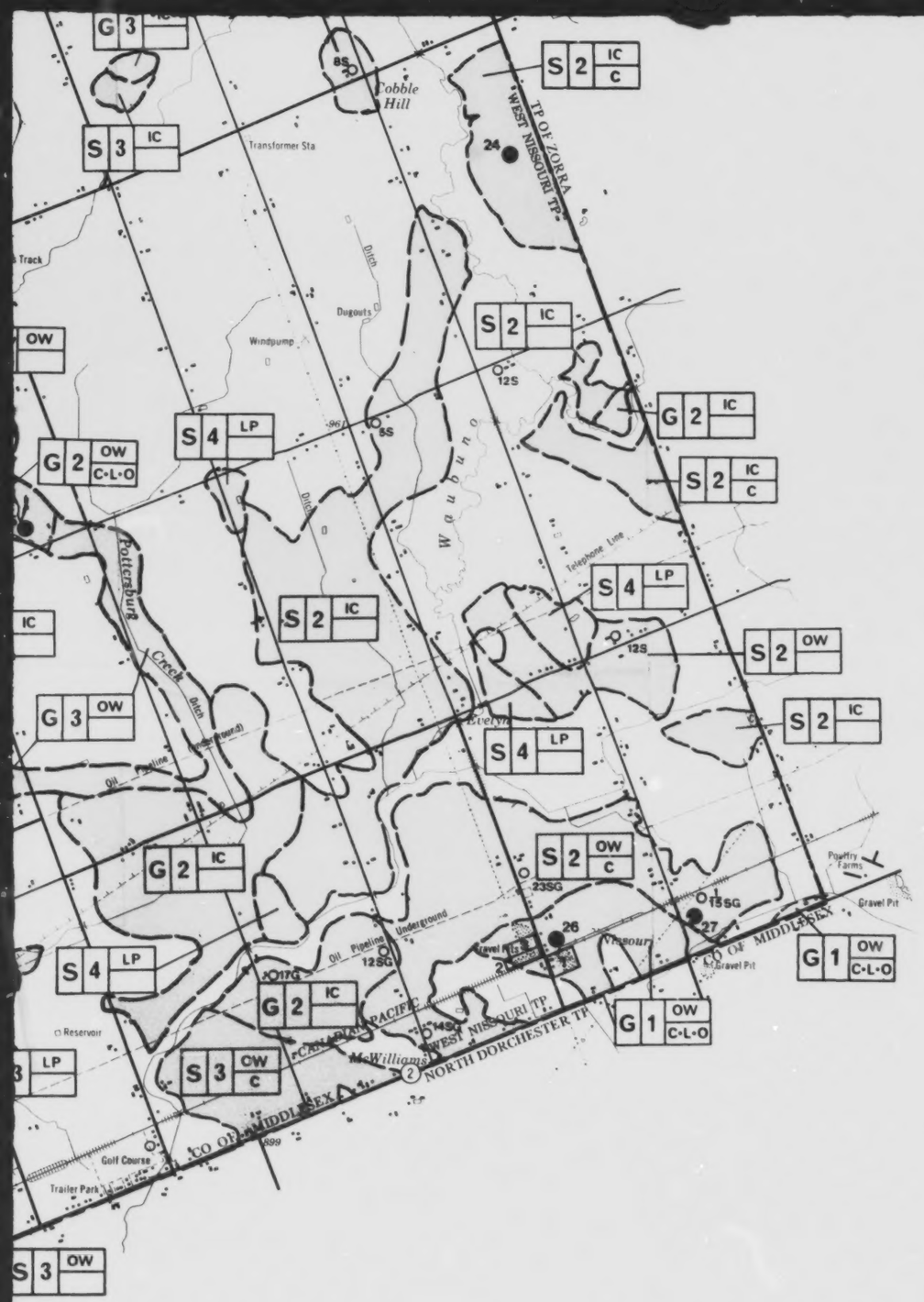
Licence data from District and
Resources.

Aggregate suitability data fro
Ministry of Transportation a

Test hole data from Aggregate
Ontario Ministry of Natural

Selected drilled water well data

Drilling data from the Petrole
Natural Resources.



WEST NISSOURI

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

2 — Licenced property boundary; Property number: see Table 2.

3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

WN·TH·2 — Selected test hole location; Identification number: see Table 7.

6 / 23 G — Selected drilled water well location; reported thickness of material (in feet); reported type of material (number only - overburden, T - till, G - gravel, S - sand, C - clay, Bk - bedrock).

G 1 IC C·O — Deposit Symbol: see below.

Texture symbol: see below.

TEXTURE SYMBOL

(This symbol is used where sample analysis data are available.)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12, 500 (< 28 000)

Geological Type

AL	Older Alluvium	**K**	Kame
E	Esker	**LB**	Lacustrine Beach
EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
ICT	Ice-Contact Terrace	**OW**	Outwash
		WD	Windblown Forms

(see Appendix C for descriptions of Geological Types)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Natural Resources.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: E. V. Sado and U. J. Vagners, 1975.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

This map is to accompanv O.G.S. Aggregate Resources Inventory Paper 77.

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Issued 1984.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

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Ontario

Ministry of Natural Resources

Hon. Alan W. Pope
Minister

J. R. Sloan
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

WEST NISSOURI TOWNSHIP

COUNTY OF MIDDLESEX

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **40 P/3**

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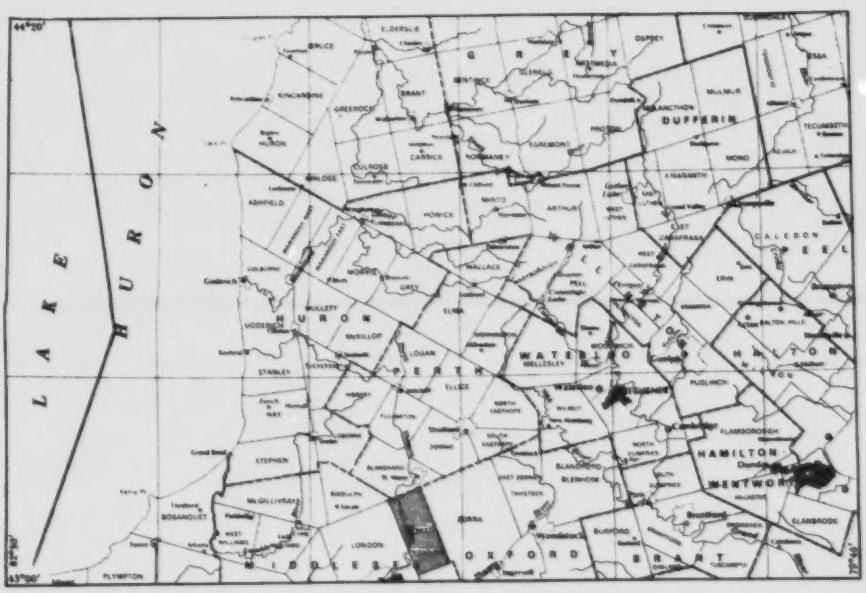

SYMBOLS

(Some symbols may not apply to this map.)

— — — — Geological and aggregate thickness boundary.

•••••••••••••••••• Buried geological and aggregate thickness boundary.

——— – ——— Municipal boundary.

Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.

Base map by Survey
sources.
Licence data from D
Resources.
Aggregate suitability
Ministry of Trans

Geology by: E. V.

Compilation and D

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Ontario Geologica

Issued 1984.

WEST NISSOURI

...ological and aggregate thickness boundary.

Municipal boundary.

Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.

Selected sand and gravel resource area; Secondary significance.

Selected sand and gravel resource area; Tertiary significance.

2 — Licenced property boundary; Property number: see Table 2.

3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: E. V. Sado and U. J. Vagners, 1975.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 77.

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Issued 1984.

DETROIT RIVER GROUP
LUCAS FORMATION

DUNDEE FORMATION

DUNDEE FORMATION

BLANSHARD TP
WEST NISSOURI TP

CO OF PERTH
CO OF MIDDLESEX

BIDDULPH TP

CO OF MIDDLESEX

WEST NISSOURI TP
LONDON TP

OXFORD CO
CO OF MIDDLESEX

NORTH THAMES

CANADIAN NATIONAL

Gregory Creek

Cherry Grove

Wellburn

Devizes

Kellys

Belton

St Ives

Plover Mills

Friendly Corners

Salmonville

Oliver

Cobble Hill

Orchard

Dugouts

Dugout

Poultry Farm

Feed Mill

Auto Wreckers

Pumping Sta

Silo

Ditch

Fence

Power Transmission Line

Gas Pipeline (underground)

Oil Pipeline (underground)

Control Valve

BM 1048

BM 1077

105

132

127

133

130

162

124

226

110

180

170

121

116

396

999

440

155

PALEOZO
DEVO

Ministry of Natural Resources

Ontario

Hon. Alan W. Pope
Minister

J. R. Sloan
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

WEST NISSOURI TOWNSHIP
COUNTY OF MIDDLESEX

MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **40 P/3**

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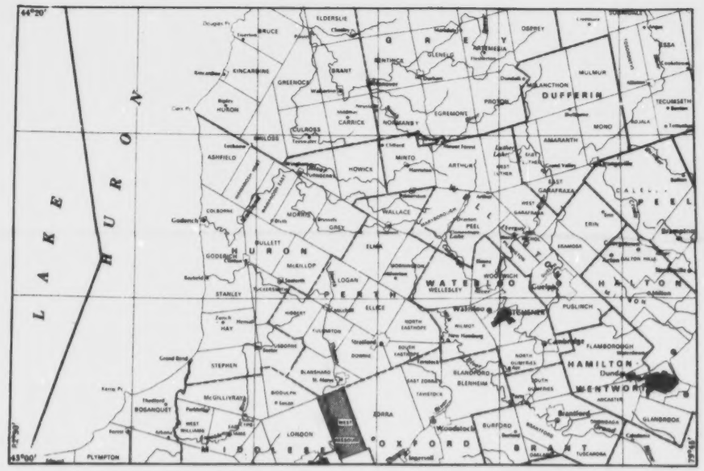

LEGEND

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

DUNDEE FORMATION
Limestone

DETROIT RIVER GROUP

SYMBOLS

(Some symbols may not apply to this map.)

— — — — Geological formation boundary.

- - - - - - Geological formation member boundary.

— • — • — Formation thickness boundary (see text).

——25—— Drift thickness contour: 25 foot (8 m) interval.

—— - —— Municipal boundary.

WEST NISSOURI

Base map by Surveys and Mapp
sources.
Licence data from District and
Resources.
Aggregate suitability data from
Ministry of Transportation an
Selected drilled water well data f
Drilling data from the Petroleu
Natural Resources.

WEST NISSOURI

MIDDLE DEVONIAN

DUNDEE FORMATION
Limestone

DETROIT RIVER GROUP
LUCAS FORMATION
Limestone and dolostone

Formation thickness boundary (see text).

25 Drift thickness contour: 25 foot (8 m) interval.

Municipal boundary.

2 Selected bedrock resource area; Deposit number: see Table 6.

Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.

Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.

Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.

x Isolated bedrock outcrop.

Q2 Licenced quarry boundary; Property number: see Table 5.

Q3 Unlicenced quarry*; Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.

26 Selected drilled waterwell location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: E. V. Sado and D. Jones, 1980.
B.V. Sanford, 1969.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

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